

Vitamin Content of Ethylene-treated and Untreated Tomatoes*

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THE use of ethylene gas for the forced coloration of certain fruits and vegetables, such as citrus fruits, bananas, and tomatoes, has recently attracted much attention from both the commercial and the nutritional standpoints. By this process the development of color characteristic of the ripe fruit can be materially hastened in green, unripe fruit either before or after shipment; and the period during which the fruit can be stored, or shipped from warm to colder regions in advance of the local season, lengthened. It also results in products more uniformly colored, having a firmer texture, and less subject to injury from handling, than those allowed to ripen naturally before being gathered. Ethylene has also been found efficacious in removing the astringency of certain fruits, such as persimmons, due to the presence of tannins.

It has been long known that the coloring or ripening of certain fruits can be hastened by placing the fruit in closed rooms or tents in which oil or almost any other fuel is being burned. The effects were at first attributed to increased temperature and humidity. In 1912 Sievers and True,¹ working on the "sweating" process of ripening citrus fruit, discovered that the hastening of the coloring of lemons was caused by the action of gaseous products of incomplete combustion. Following up this work Denny² showed that the constituents of these gases that were most effective were unsaturated hydrocarbons, notably ethylene. In 1923 Denny³ secured a patent covering the use of ethylene for the forced coloration of fruit. Chace and Denny in 1924⁴ contributed additional data on this process.

The blanching effect of ethylene and other constituents of illuminating gas on plants had been early observed by Kroker and Knight,⁵ Schonnard,⁶ and others. Other contributions on the application of ethylene to the coloration of fruits and the blanching of celery have been made by Chace and Church,⁷ Rosa,⁸ and Harvey.⁹

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Soon after the announcement of the ethylene process for treating fruits and vegetables, the *Journal of the American Medical Association*, recognizing the possible harmful effect upon their nutritive value that might result from chemical treatment of foods, particularly with reference to the vitamins, called attention* to the need of work to develop information regarding the effect, if any, of the ethylene process on vitamins.

In view of the work that had been done in the U. S. Department of Agriculture on the study and development of the ethylene treatment of fruit, and in conjunction with a continuation of investigation on this subject by the Food Research Division of the Bureau of Chemistry and Soils, we undertook a study of the comparative vitamin value of tomatoes treated and untreated with ethylene gas, and collected at different stages of development.

PREPARATION OF THE MATERIAL*

The tomatoes used were a pure bred strain grown specially for the ethylene studies on the U. S. Department of Agriculture experiment farm at Arlington, Va.

They were collected at three stages of development, immediately washed with water, and handled as follows: Green tomatoes in two stages of maturity were divided into four lots. The lots to be treated with ethylene were placed in earthen jars; ethylene gas was introduced in the proportion of 1 part in 1,000; and the lids were sealed.

The tomatoes were removed from the jars daily, dried and aired, then replaced; fresh ethylene gas was introduced, and the jars were resealed. After treatment with the gas for 5 days, they were ground in a meat grinder, thoroughly mixed, heated in a steam bath, and placed in cans while hot, sealed and processed according to usual cannery practice.

The portions untreated with gas were ground as soon as picked, processed and canned in the manner and under conditions identical with those described for the gas treated tomatoes.

In addition to the green tomatoes referred to, others that had been allowed to ripen naturally on the vines were likewise canned.

There were thus prepared for the vitamin studies five different lots of tomatoes referred to as follows:

Lot 1—Mature, green tomatoes, untreated; i.e., full grown fruit in which the chlorophyl had begun to fade, but which were not ripe

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Lot 2—Tomatoes naturally ripened on the vines—untreated

Lot 3—Immature, green tomatoes, walnut size, untreated, in which the chlorophyll had not begun to fade

Lot 4—Mature, green tomatoes, similar to *Lot 1*, treated with ethylene

Lot 5—Immature, green tomatoes, similar to *Lot 3*, treated with ethylene

After being canned, the tomatoes were placed in cold storage.

There were marked differences in the proportion of solid material to juice in the different lots. The cans of mature, ripened tomatoes contained more juice than did the green, immature fruit.

Since tomato juice is used extensively and frequently recommended in infant feeding, and our feeding technic could be greatly facilitated by using the juice, only that portion of the fruit which passed through a fine muslin cloth was used in our vitamin tests.

Owing to the possibility of retention of some of the vitamins in the pulp the results obtained may not represent the full vitamin potency of the tomatoes used. We were interested in comparative rather than absolute values.

The following observations on the canned fruit were noted: *Lot 1* showed the development of a little red color. *Lot 2* was more deeply colored than *Lot 4*, although the latter was well within the range of color of commercially canned tomatoes. *Lot 5* was slightly darker in color than *Lot 3*, the small untreated tomatoes. There was no evidence of any lycopin formation in *Lot 5*. We found a marked difference in the quantity of juice that could be expressed from the crushed fruit, depending upon whether or not the tomatoes had been treated with ethylene and also upon the stage of maturity. The average amount of juice obtained in three separate trials was as follows:

Lot 1, 71 per cent

Lot 2, 82 per cent

Lot 3, 62 per cent

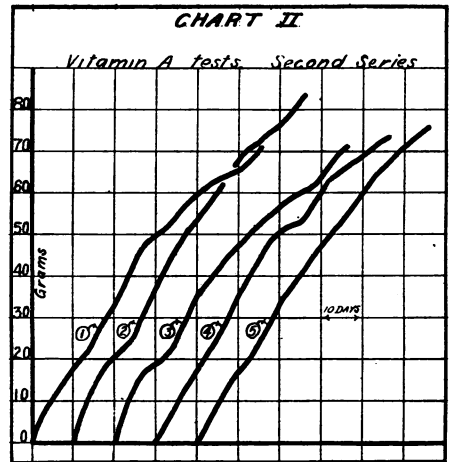
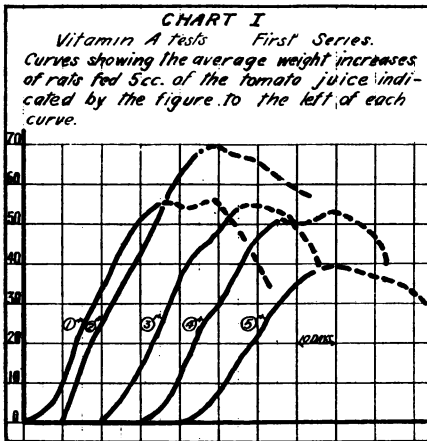
Lot 4, 77 per cent

Lot 5, 70 per cent

VITAMIN A

Curative vitamin A tests were conducted essentially according to our technic as described elsewhere.²¹ In the first series four litters of rats showing definite signs of ophthalmia were divided into six groups, each consisting of 2 males and 2 females, 1 animal from each of the four litters. Five groups were fed 5 c.c. of tomato juice daily from each of the five lots of tomatoes as indicated by the figure to the left of each curve in Chart I. The remaining group served as a negative control. The A-deficient diet consisted of alcohol extracted casein, 18 per cent; salt mixture (Osborne and Mendel's), 4 per cent; agar, 2 per cent; yeast, 8 per cent; dextrinized starch, 67 per cent; and peanut oil, 1 per cent. Of the yeast used 0.5 per cent had been irradiated, and its vitamin D potency had been determined.

The tomato feeding was discontinued at the end of 5 weeks, and the animals were then kept on the basal diet until they showed considerable loss in weight. As shown in Chart I the rats which received the naturally ripened tomatoes, Lot 2, made distinctly better gains



than those of the other groups. The control rats survived an average of 23 days from the time their litter mates were first fed tomatoes, and all developed severe cases of ophthalmia before death. The other groups all showed improvement of the eyes during the tomato feeding period, but there were no definite cures of ophthalmia. The group receiving tomato juice, Lot 5, did not react differently from the other groups notwithstanding uniformly poorer growth. The sharp breaks in the curves when the tomato juice was withdrawn from the diet shows that the level of tomato fed did not permit storage of vitamin A.

The second series of tests was conducted in the same manner as the first, except that the tomato feeding was carried on for 8 weeks, and the experiment then terminated (Chart II). As in both series of tests the rats receiving Lot 2 tomato juice grew more rapidly than those on any other lot, it is evident that the naturally ripened tomato is the best source of vitamin A. No explanation is offered for the fact that in the first series the rats on Lot 5 did not grow so well as those of the other groups. There was very little individual variation within the group. In the second series the Lot 5 rats showed the largest average gain, with the exception of Lot 2, due to the exceptionally rapid growth of one animal.

At the end of 5 weeks the following average gains had been made in each of the ten groups:

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
First Test	55	68	54	51	38
Second Test	54	60	52	53	53

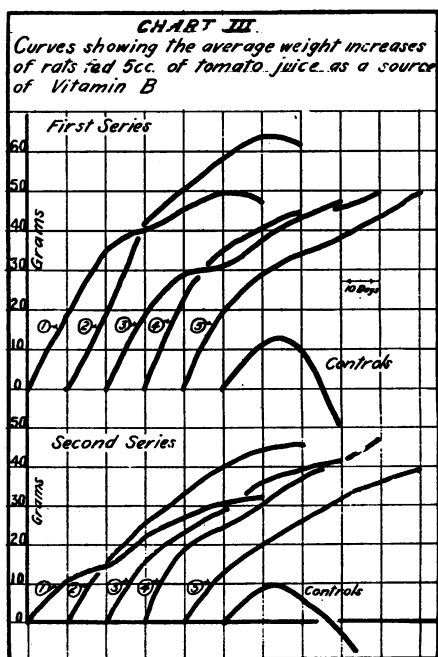
VITAMIN B

In the vitamin B tests the following diet was used: Alcohol extracted casein, 18 per cent; salt mixture, 4 per cent; agar, 2 per cent; cod liver oil, 2 per cent; autoclaved yeast, 5 per cent; and dextrin, 69 per cent. The yeast was autoclaved 4 hours at 15 lb. pressure, and previous tests had shown it to be free from the antineuritic vitamin. The casein was similar to that used in the vitamin A tests just described.

In the first series of tests four litters of rats weighing about 60 gm. each were divided into six groups comparable as to size, sex, and parentage. One group received only the basal diet while the others received 5 c.c. per day of the different lots of tomatoes for a period of 60 days. Each curve for the first series seen in the upper portion of the chart shows the average weight increase of 4 rats, 2 males and 2 females. As shown on Chart III the fully ripened tomatoes, Lot 2, were distinctly superior as a source of vitamin B to the other lots, which were all about the same.

Each curve of the second series, begun nearly 3 months later, represents the average weight of 4 male rats. Not more than one animal from one litter was used in a group. In no case did the rats in the second series grow as rapidly as those in the first and there was not the same degree of response in comparable groups. The average gain for all the males in the first series (2 rats in each group) was 53 gm. The average gain in weight for all rats in the second series (all males) was 41 gm. Evidently a marked loss of vitamin B occurred in the canned tomatoes during the period intervening between the two series of tests.

The average survival of the control rats in the first series was 31 days and the second series 41 days. One of the controls in the



first series died at the end of 20 days, about 10 days less than the minimum survival period usually observed.

VITAMIN C

As in the vitamin A and B tests, the vitamin C assays were conducted on two sets of animals. In the first series the interpretation of the results is based upon symptoms of scurvy in the living animals and post-mortem examinations. In the second series, data on survival of the animals were also obtained. The two sets of experiments will be discussed separately. Twenty-eight guinea pigs weighing from 280 to 325 gm. were divided into seven equal groups, five of which received 1 c.c. of tomato juice from the different lots of tomatoes. The other two groups were used as controls. One group received 2 c.c. of orange juice daily, and the other served as a negative control. The basal diet consisted of rolled oats, 69 parts; alfalfa, autoclaved 30 minutes, 25 parts; casein, 5 parts; and sodium chloride, 1 part.

At the end of one month only one control animal showed definite symptoms of scurvy, and the other animals were all apparently normal, with the exception of a slow growth rate in many. Evidently our basal diet was not free from vitamin C. Alfalfa which had been autoclaved 90 minutes was then substituted for that which had been autoclaved 30 minutes. In 2 weeks all of the negative controls showed marked symptoms of scurvy, as did the two groups receiving tomatoes, Lots 3 and 5. Three animals in each of the groups receiving tomatoes, Lots 1 and 4, showed distinct signs of scurvy before the experiment was terminated. None of the animals receiving the naturally ripened tomatoes, Lot 2, nor those receiving orange juice showed any signs of scurvy. The only marked difference between these two groups was the more rapid rate of growth of the orange juice fed animals.

At the end of 58 days the animals were killed and post-mortem examinations made. The groups receiving tomato juice, Lots 3 and 5, and the negative controls all showed severe scurvy. Extensive subcutaneous hemorrhages, brittle bones, and frequently loose teeth were the most conspicuous findings. Three animals in each of the groups receiving tomatoes, Lots 1 and 4, showed subcutaneous hemorrhages, while the remaining animal in each group was apparently normal. Those receiving Lot 2 gave no post-mortem evidence of scurvy.

Before starting the second series of tests we demonstrated that the alfalfa we were using contained a considerable quantity of vitamin C and that if it were autoclaved 90 minutes the animals would develop scurvy in about 3 weeks. Consequently, the alfalfa was autoclaved 90 minutes in our later work.

The second series of tests on the tomato juice was conducted on the same number of guinea pigs, all virgin females, weighing from 250 to 297 gm. The levels of tomato and orange juice fed were the same as in the previous series. Because of the differences in vitamin C content of the various lots of tomatoes, we obtained data on the survival of the animals. At the end of 90 days when the experiment was terminated 7 animals were alive, 1 receiving Lot 1 tomato juice, 2 receiving Lot 2, and 4 receiving orange juice.

Table I gives the days of survival of the animals used.

TABLE I

<i>No Vitamin C</i>	<i>Lot 1</i>	<i>Lot 2</i>	<i>Lot 3</i>	<i>Lot 4</i>	<i>Lot 5</i>	<i>Orange Juice</i>
36	61	59	35	51	56	90
40	90	50	35	44	31	90
41	59	90	48	22	34	90
35	51	90	17	46	43	90

With the exception of the guinea pigs receiving orange juice and 2 animals receiving Lot 2 tomato juice, all of the animals showed unmistakable symptoms of scurvy at the end of 3 weeks. One animal on Lot 1 which survived the experimental period was inactive during the last 40 days, and showed complete loss of control of the hind legs. The 2 animals on Lot 2 which survived the experimental period remained active until the end. At times their wrists were sore and swollen, but scurvy symptoms were transient. Post-mortem examinations revealed evidence of scurvy in both of these animals. All animals which died showed severe scurvy upon post-mortem examination. The control animals all made a steady average gain of about 3 gm. per day until the experiment was terminated.

DISCUSSION

The most practically significant result is probably the evidence obtained showing that naturally ripened tomatoes are a better source of vitamins A, B, and C than any of the others studied, either treated or untreated with ethylene gas.

No material difference was observed in the vitamin A content of the green tomatoes picked at different stages of development, whether or not treated with ethylene. The same was true of the vitamin B content of the different lots as determined in the first series of tests.

The vitamin C value of tomatoes seems to increase as the fruit develops and approaches the mature ripened condition. Naturally ripened tomatoes contained the most vitamin C, full grown, green tomatoes came next, and the small, immature fruit contained the least of all. The ethylene treatment of the green tomatoes produced no

significant change in their vitamin C potency, which was low in all samples of the green fruit tested. The second series of tests for vitamin B gave lower values than obtained in the first series with samples of the same lots. Apparently a loss of this vitamin occurred on storage, for which we have no explanation.

After the work described was well under way, two articles on this subject appeared. Morgan and Smith¹² found that ripe tomatoes were richer in vitamin A than green tomatoes, but that the amount in ripe tomatoes was about the same, irrespective of the methods used in ripening. House, Nelson, and Haber¹³ found that green and ripe tomatoes contained essentially the same amount of vitamin B, irrespective of the methods used in ripening. They also found more vitamin A in ripened than in green tomatoes, but the tomatoes ripened by the different methods had the same amount. Their results on vitamin C are in agreement with ours. Our results cannot be satisfactorily compared with those of House, Nelson, and Haber, because these authors fed the whole tomato, while we fed only the juice. Furthermore, they do not give sufficient details regarding the handling of the tomatoes after having been picked from the vines, and they make no statement regarding the length of time the tomatoes were treated with ethylene.

In so far as the use of tomato juice as a source of vitamins is concerned the results of our work indicate that vine-ripened tomatoes are preferable to those picked green and treated with ethylene gas to develop the color characteristic of ripe fruit. No indication was observed that the ethylene treatment had any deleterious effect upon vitamins already developed.

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